THE EFFECTS OF VEGETATION ON THE DYNAMIC STATE OF THE GROUND

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ABSTRACT

The Battlespace Terrain Reasoning and Awareness (BTRA) research program edict for the Future Combat System(s) (FCS) is to "provide warfighters with an accurate and timely understanding of the battlespace environment's effect on personnel, platforms, sensors and systems in order to develop improved tactics, techniques, procedures and plans that insure information superiority and situational awareness" (R. Davis, ERDC-CRREL, personal communication). BTRA is developing tools which will be embedded in DTSS (Digital Topographic Support System) and CJMTK (Commercial Joint Mapping Tool Kit). These tools will "use measured and forecasted weather to predict weapon sensor performance and weather influences upon on- and off-road mobility; to analyze and predict maneuver options by looking at cover, concealment, defensible positions, etc.; and to perform automated terrain analysis based on enemy doctrine, equipment constraints, operational posture and terrain effects" (M. Powers, ERDC-TEC, personal communication). As part of the BTRA program we developed a dynamic state of the ground model, FASST (Fast All-season Soil STrength) to provide input to mobility (STDMOB) and infrared and acoustic sensor performance overlay algorithms (RSPD and SPEBE respectively). This model predicts the soil moisture, ice content, temperature and strength as well as snow and ice accretion/depletion as a function of meteorological forcing and site characteristics. Recently, a two tier, multilayer vegetation algorithm was added. We will start by briefly discussing the original model followed by details of the new vegetation subroutines. How the vegetation affects the above model outputs will also be presented.

1. INTRODUCTION

The fundamental operations of FASST are the calculation of an energy and water budget that quantify both the flow of heat and moisture within the soil and also the exchange of heat and moisture at all interfaces (ground-air, ground-snow; snow-air) using both meteorological and terrain data (Frankenstein and Koenig, 2004a). FASST is designed to accommodate a range of users from those who have intricate knowledge of their site to those who only know the site location. It allows for 22 different terrain materials, including asphalt, concrete, bed rock, permanent snow and the USCS soil types. At a minimum, the only weather data required is the air temperature.

In this paper we will limit our discussion to the energy balance equations used to solve for the low vegetation, canopy and ground temperatures. In solving these equations, the effects of precipitation interception and soil moisture modification due to root-uptake have been incorporated. Details concerning the low vegetation and canopy models discussed below are found in Frankenstein and Koenig (2004b).

2. LOW VEGETATION MODEL

The energy budget of a simple vegetation layer on a soil surface is modeled using a steady-state semi-infinite plane parallel model (Balick et al., 1981; Deardorff, 1978) which is described by the foliage emissivity ε_f and albedo α_f, a foliage height Z_f and the foliage fractional coverage σ_f. The low vegetation model consists of a single homogeneous layer that is infinite in the *x* and *y* direction. It incorporates grasses, shrubs, marsh, tundra and dessert vegetation.

The sum of the energy terms at both the vegetation /air and vegetation/ground interface, consisting of the absorbed solar and infrared fluxes, the emitted longwave flux, and the sensible, latent and precipitation heat fluxes, is equal to zero at each time increment. The solution of the resulting two polynomial equations of degree *n*, for the low vegetation and the ground temperatures is obtained using a root-finding algorithm.

3. CANOPY (TREE) MODEL

The canopy model is based on the model developed by (Smith et al., 1981). It is a semi-infinite, steady-state plane parallel energy budget model consisting of three canopy layers, an atmospheric layer above the canopy, and a ground layer below the canopy. Each layer acts as both a source and a sink of energy. The model considers the longwave and shortwave fluxes and the interactions between the various layers. The longwave absorption coefficients are unique in that these coefficients are relative to the infrared flux at the top of the canopy rather than the infrared flux at the top of the individual canopy

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layers. The absorption coefficients are calculated using a Monte Carlo technique and include the effects of multiple scattering.

The canopy model uses the approach introduced by Deardorff (1978) for the sensible and latent heat flux calculations. Unlike Smith et al. (1981) a precipitation heat term is included in the canopy energy balance. The canopy temperatures are solved for using a Newton-Raphson technique. The model also incorporates the orientation and distribution of leaves in the canopy layers. Five types of trees are modeled, needle leaf and broadleaf evergreens, needle leaf and broadleaf deciduous and mixed.

4. RESULTS

We ran four simulations; bare soil, tall grass, broadleaf deciduous canopy, and combined grass and canopy. The low vegetation and mean canopy densities were 78% and 65% respectively. The canopy and meteorological data were collected in Grayling, MI during the fall of 1992 as part of SWOE (Smart Weapons Operability Enhancement). The results can be seen in Figures 1 and 2. Further results are presented in Frankenstein and Koenig (2004b).

The most notable change when combining the canopy and grass layers in the soil moisture is the decreased soil moisture during storm events (peaks). As can be seen in Figure 1, this is almost entirely due to the low vegetation which intercepts much of the precipitation. The roots tend to mitigate the diurnal variations and prevent the soil from drying to the extent of the bare soil case.

Surface temperatures for each of the scenarios are shown in Figure 2. As with the soil moisture, the low vegetation appears to influence the soil temperature more than the canopy. For instance, on day 278 the maximum/minimum surface temperatures (K) for the bare soil, canopy only, low vegetation only and combined forecasts are 296.78/277.69, 297.56/280.21, 287.53/277.71 and 290.34/279.33 respectively. This could be due to the proximity of the foliage to the soil.

5. CONCLUSIONS

As can be seen, vegetation has the potential to alter the soil surface properties. This affects the operational capacity of infrared sensors which rely on the signal differences between the target and the background. Also, mobility calculations are based, in part, on soil moisture. Depending on the soil type, the change in moisture due to vegetation could determine whether the situation is go or no-go. These are just two examples of the impact vegetation can have on military operations.

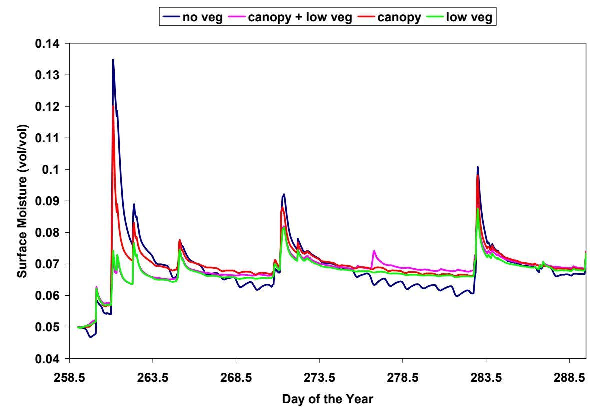

Figure 1 Soil moisture comparisons for Grayling, MI.

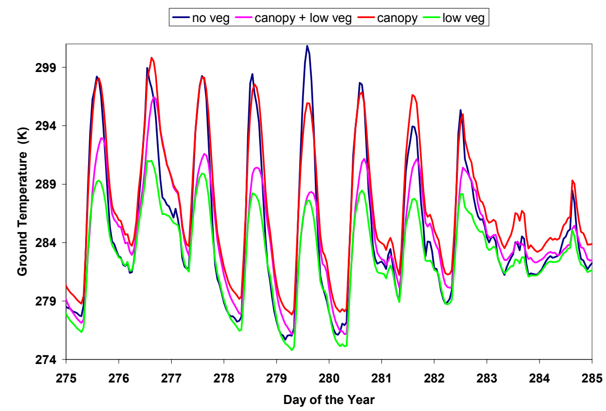

Figure 2 Soil surface temperature comparisons for Grayling, MI.

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